CLAIMS

What is claimed is:

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1. A laser system comprising:

a seed source generating pulses in the 1 - 1.15 μm wavelength region which have a spectral bandwidth larger than 0.3 nm and a pulse width between approximately 50 fs and 1 ns;

a fiber amplifier for broad bandwidth pulses which inputs and amplifies said pulses, and outputs amplified pulses; and

a pump laser for providing laser energy to said fiber amplifier.

2. A laser system according to claim 1, wherein the seed source comprises:

a fiber laser;

a Raman-shifter which inputs the output of said fiber laser; and

a nonlinear crystal which frequency-doubles the output of said Raman-shifter.

3. A laser system according to claim 2,

wherein the Raman-shifter is a silica-based fiber which up-converts the emission wavelength of said fiber laser to a spectral range longer than 2000 nm;

and further wherein said nonlinear crystal subsequently down-converts the up-converted wavelength to the spectral range from 1000 - 1500 nm.

4. A laser system according to claim 2, wherein the wavelength tuning curve of the nonlinear crystal is below the center wavelength of the output of the Raman-shifter.

5. A laser system according to claim 2, wherein said Raman-shifter comprises non-amplifying fibers or amplifying fibers with refractive index profiles and rare-earth amplifier ions selected to generate pulses within a wavelength range of approximately 600-5000 nm.

6. A laser system according to claim 1, wherein the seed source comprises:

an Er fiber laser;

a silica Raman-shifting fiber which inputs the output of said Er fiber laser and outputs to said fiber amplifier; and

a fluoride Raman shifter which inputs said amplified pulses,

wherein said fiber amplifier is a Tm fiber amplifier.

7. A laser system according to claim 6, further comprising:

a nonlinear crystal which inputs an output of said fluoride Raman-shifting fiber so as to perform frequency-doubling thereon.

8. A laser system according to claim 1, wherein the seed source comprises:

an Er fiber laser;

a nonlinear crystal which inputs an output of said Er fiber laser so as to perform frequency-doubling thereon; and

a Raman-shifter which inputs the frequency-doubled output of said non-linear crystal.

9. A laser system according to claim 8, wherein the seed source is a passively modelocked fiber laser, and further wherein said Raman shifting fiber is a holey fiber which is used to Raman-shift the frequency-doubled output of the nonlinear crystal from a wavelength range of approximately 750 nm to approximately 1050 nm.

10. A laser system according to claim 8, wherein the seed source is a passively modelocked fiber laser, and further wherein a range of non-amplifying fibers and amplifying fibers with different refractive index profiles and different rare-earth amplifier ions are used to Raman-shift the frequency-doubled output of said nonlinear crystal from the wavelength range of around 750 nm to around 5000 nm.

11. A laser system according to claim 1, wherein the seed source comprises a passively modelocked fiber laser.

12. A laser system according to claim 11, wherein the passively modelocked fiber laser is a Yb fiber laser.

13. A laser system according to claim 11, wherein the passively modelocked fiber laser is a Nd fiber laser.

14. A laser system according to claim 11, wherein the passively modelocked fiber laser is multi-mode.

15. A laser system according to claim 14, wherein the passively modelocked fiber laser is polarization maintaining.

16. A laser system according to claim 11, wherein the passively modelocked fiber laser is single-mode and polarization maintaining.

17. A laser system according to claim 1, wherein the seed source comprises:

a fiber laser; and

a frequency-shifting fiber which inputs the output of said fiber laser and outputs an anti-Stokes, blue-shifted output.

18. A laser system according to claim 17, wherein said fiber laser is an Er, Er/Yb, Pr or Tm fiber laser.

19. A laser system according to claim 1,

wherein the seed source produces pulses which induce the formation of parabolic pulses within said fiber amplifier.

20. A laser system according to claim 19, further comprising:

a coupler between the seed source and the fiber amplifier, which couples the seed source to the fiber amplifier, and which further comprises an optical fiber with a length less than 1 km.

21. A laser system according to claim 1, further comprising:

an optical delivery fiber coupled to the output of the fiber amplifier.

22. A laser system according to claim 21, wherein said optical delivery fiber is selected from the group consisting of: a holey fiber, a length of few-moded fiber and a length of few-moded fiber spliced together with one or two lengths of single-mode fiber.

23. A laser system according to claim 22, wherein said seed source produces pulses shorter than 100 ps, so as to induce the formation of parabolic pulses within said fiber amplifier, and further wherein said fiber amplifier has a gain larger than 10.

24. A laser system according to claim 23, further comprising

a pulse stretcher which receives the pulses from said seed source, dispersively stretches said pulses in time, and outputs said stretched pulses to said fiber amplifier.

25. A laser system according to claim 24, further comprising:

a pulse compressor for temporally compressing said amplified pulses;

wherein the dispersion of the pulse compressor is such that the pulse compressor outputs approximately bandwidth-limited pulses.

26. A laser system according to claim 1, wherein the seed source comprises:

a Tm or Ho fiber laser; and

a nonlinear crystal which inputs an output of said Tm or Ho fiber laser, and performs frequency-doubling thereon.

27. A laser system according to claim 1, wherein the fiber amplifier is either Nd or Yb doped.

28. A laser system according to claim 1, further comprising:

a pulse compressor for temporally compressing the amplified pulses to approximately their bandwidth limit.

29. A laser system according to claim 1, wherein the seed source is a directly modulated semiconductor laser.

30. A laser system comprising:

a seed source generating pulses in the 1 - 1.15 μm wavelength region which have a spectral bandwidth larger than 0.3 nm and a pulse width between approximately 50 fs and 1 ns;

a pulse stretcher which receives said pulses, dispersively stretches said pulses in time, and outputs said stretched pulses;

a cladding-pumped fiber amplifier, having a gain larger than 10, for broad bandwidth pulses which receives, amplifies and outputs said stretched pulses; and

a pulse compressor which inputs said amplified stretched pulses and temporally compresses them to approximately their bandwidth limit.

31. A laser system according to claim 30, wherein said pulse stretcher comprises a fiber with a length less than 1 km.

32. A laser system according to claim 30, wherein said pulse stretcher comprises a holey fiber.

33. A laser system according to claim 30, wherein said pulse stretcher comprises a length of few-moded fiber.

34. A laser system according to claim 30, wherein said pulse stretcher comprises a length of few-moded fiber spliced together with one or more lengths of single-mode fiber.

35. A laser system according to claim 30, wherein said pulse stretcher comprises a single-mode fiber with a length less than 1 km

36. A laser system according to claim 30, wherein said pulse stretcher comprises a fiber with a W refractive index profile

37. A laser system according to claim 30, wherein said pulse stretcher comprises a fiber with a multi-clad refractive index profile.

38. A laser system according to claim 30, wherein said pulse stretcher comprises:

a length of fiber with negative 3rd order dispersion; and

a linearly chirped fiber grating with negative 2nd order dispersion.

39. A laser system according to claim 30, wherein said pulse stretcher comprises:

a linearly chirped fiber grating; and

one or more fiber transmission gratings with selectable values of 3rd and higher-order dispersion, so as to compensate for the higher order dispersion in the pulse compression means.

40. A laser system according to claim 30, further comprising:

an plurality of additional fiber amplifiers connected between said pulse stretcher and said pulse compressor;

a fiber coupler coupling the seed source to a first one of the plurality of additional fiber amplifiers, said fiber coupler comprising an optical fiber with a length less than 1 km; and

a plurality of pulse picking means located either before the fiber amplifier, after the plurality of additional fiber amplifiers, or in-between any of the amplifiers.

41. A laser system comprising:

a seed source generating pulses in the 1 - 1.15 μm wavelength region which have a spectral bandwidth larger than 0.3 nm and a pulse width between approximately 50 fs and 1 ns;

a cladding-pumped fiber amplifier for broad bandwidth pulses which receives, amplifies and outputs said pulses, wherein the fiber amplifier is operated with at least one forward and one backward pass; and

a pump laser for providing laser energy to said fiber amplifier, and

an optical modulator located between the one forward and one backward pass of said amplifier.

42. A laser system according to claim 41, further comprising:

a plurality of additional fiber amplifiers, wherein at least one of the fiber amplifier and the plurality of additional fiber amplifiers is operated with at least one forward and one backward pass; and

a mode filter for preferentially transmitting the fundamental mode of an amplifier located after the first pass through said at least one of the fiber amplifier and the plurality of additional fiber amplifiers which is operated with at least one forward and one backward pass.

43. A laser system according to claim 42, further comprising at least one pulse picker located between the at least one forward and one backward pass.

44. A pulse source operating at an output wavelength greater than 2 microns, comprising:

a seed source outputting short pulse-width pulses; and

a first fiber Raman shifter inputting said pulses, and producing said output wavelengh.

45. A pulse source according to claim 44, further comprising:

at least one additional fiber Raman shifter connected to said first fiber Raman shifter; and

a plurality of fiber amplifiers alternately connected between said fiber Raman shifters.

46. A pulse source according to claim 45, further comprising;

a doubling crystal connected to the last one of said fiber Raman shifters,

wherein the wavelength tuning curve of the nonlinear crystal is selected to be below the center wavelength of the Raman-spectral component of the Raman-shifted and amplified seed pulse.

47. An optical pulse source comprising:

a passively modelocked fiber laser; and

a Yb amplifier for amplifying an output of said fiber laser.

48. A optical pulse source according to claim 47, wherein said passively modelocked fiber laser comprises a Yb fiber laser.

49. An optical communications subsystem comprising:

a net positive dispersion fiber optic amplifier connected along an optical fiber transmission line having a gain less than 10 dB/km and a total gain of more than 10 dB;

a dispersion compensation element located along said optical fiber transmission line; and

an optical filter located along said optical fiber transmission line.

50. An optical communications subsystem comprising:

a net positive dispersion fiber optic amplifier connected along an optical fiber transmission line and having a gain less than 3 dB/km and a total gain of more than 20 dB; and

a dispersion compensation element located at an end of the optical fiber transmission line.

51. An optical communications subsystem comprising:

a positive dispersion optical fiber element connected along an optical fiber transmission line; and

an optical negative dispersion element also connected along the optical fiber transmission line, wherein an amount of self-phase modulation incurred by optical pulses transmitted along the optical fiber transmission line is higher in the positive dispersion optical fiber element than in the optical negative dispersion element.

52. An optical communications subsystem as recited in claim 51, wherein said optical negative dispersion element comprises chirped fiber gratings.

53. An optical communications subsystem comprising;

a plurality of lengths of holey fiber having net positive dispersion connected along an optical fiber transmission line; and

a plurality of optical negative dispersion elements also connected along the optical fiber transmission line, wherein an amount of self-phase modulation incurred by optical pulses transmitted along the optical fiber transmission line is higher in the lengths of holey fiber than in the optical negative dispersion elements.

54. An optical communications subsystem, comprising:

an optical Raman amplifier fiber which inputs a train of pump pulses having a length shorter than 10 ns and which also inputs, amplifies and outputs an optical signal, wherein said optical signal counterpropogates within said Raman amplifier fiber with respect to the pump pulses.

55. An optical communications subsystem according to claim 54, wherein said optical Raman amplifier is tuned by a tuning operation performed on said pump pulses.

56. An optical communications subsystem according to claim 55, further comprising:

a seed source which outputs optical pulses;

a modulator which modulates said optical pulses;

a Raman shifter fiber which inputs said modulated optical pulses; and

a Raman amplifier which inputs an output of said Raman shifter fiber.

57. An optical communications subsystem according to claim 56, wherein said tuning operation includes modulating at least one of the power, wavelength and the width of said seed pulses before said seed pulses are injected into said Raman-shifter fiber.

58. A laser system according to claim 9, wherein said Raman shifting fiber is a holey fiber whose dispersion varies with wavelength in a manner so as to optimize said Raman-shift.

59. A laser system comprising:

a source of seed pulses;

a fiber amplifier which inputs and amplifies said seed pulses, and outputs amplified pulses; wherein

said seed pulses are generated and said fiber amplifier is configured such that the pulses produced by said fiber amplifier are of parabolic form.

60. A laser system comprising:

a source of seed pulses;

a fiber amplifier which inputs and amplifies said seed pulses, and outputs amplified pulses; wherein

the seed source produces pulses which induce the formation of parabolic pulses within said fiber amplifier.

61. A laser system comprising:

a source of seed pulses;

a fiber amplifier which inputs and amplifies said seed pulses, and outputs amplified pulses; wherein

said seed pulses are generated and said fiber amplifier is configured such that the pulses produced by said fiber amplifier are of parabolic form.

62. An optical communications subsystem, comprising:

a source of optical pulses of differing wavelengths; and

means for dynamically modifying the degree of Raman shift experienced by each of said differing wavelengths.

63. In an optical communications system of the type including fiber optic carriers carrying optical signals of differing wavelengths and at least one fiber laser amplifier, the improvement comprising at least one Raman shifter for imposing a differential gain upon said signals of differing wavelengths..

64. A seed source for a laser system, comprising:

a fiber laser producing a pulse output;

a Raman-shifter which inputs the pulse output of said fiber laser; and

a nonlinear crystal which frequency-doubles the output of said Raman-shifter.

65. A seed source as claimed in claim 64, wherein said non-linear crystal comprises a periodically-poled ferroelectric optical material selected from the group consisting of PPLN, PP lithium tantalate, PP

$MgO:LiNbO_3$, PP KTP, and a periodically poled crystal of the KTP isomorph family.

66. A seed source as claimed in claim 65, wherein a length of said non-linear crystal is selected in order to control the pulse length of a pulse output of said seed source.

67. A seed source as claimed in claim 65, wherein a wavelength of an output of said non-linear crystal is controlled by controlling a temperature of said non-linear crystal.

68. A delivery system for a fiber laser system operating in a parabolic pulse regime, comprising:

a delivery fiber;

a grating-based pulse compressor; and

a W-fiber for compensation of 3rd order dispersion of said pulse compressor.

69. A dispersion compensation arrangement for a fiber laser amplification system operating in a parabolic pulse regime, comprising:

a pulse stretcher arranged prior to an amplifier section of said system, and including at least one negative 3rd order dispersion producing element; and a pulse compressor arranged following said amplifier section, for compensating 2nd order dispersion, and having a positive 3rd order dispersion which cancels that introduced by said stretcher.

70. A dispersion compensation arrangement for a fiber laser amplification system operating in a parabolic pulse regime, comprising:

a pulse stretcher arranged prior to an amplifier section of said system, and including at least one positive 2nd order dispersion producing element and at least one of a Bragg fiber grating and a fiber transmission grating for introducing 3rd and 4th order dispersion; and a pulse compressor arranged following said amplifier section, for compensating 2nd order dispersion, and having 3rd and 4th order dispersion which cancels that introduced by said stretcher.

71. A wavelength tunable Raman amplifier, comprising:

a source of femtosecond regime seed pulses;

a Raman-shifting fiber receiving and wavelength-shifting said seed pulses to form pump pulses;

a Raman amplifier fiber injected with a plurality of signal wavelength pulses which counterpropagate with said pump pulses; and

means for modulating at least one of power, wavelength and width of said seed pulses to wavelength tune said pump pulses, to tune a center wavelength of Raman gain of said Raman amplifier.

72. An amplifier as claimed in claim 71, wherein said pump pulses are wavelength tuned within a time period less than a signal pulse traversal time of said Raman amplifier, so as to subject said signal pulses to an effective modified Raman gain spectrum.

73. A wavelength-tunable laser system, comprising:

a fiber laser which generates a pulse output having a pulse duration of less than 1 nanosecond; and

a holey fiber whose dispersion varies with wavelength in a manner so as to optimize the wavelength tuning

74. A wavelength-tunable laser system, comprising:

a fiber laser which generates a pulse output;

a holey fiber whose dispersion varies with wavelength in a manner so as to optimize wavelength tuning;

wherein, within a wavelength tuning range, said holey fiber exhibits a negative 2^{nd} order dispersion, has a 2^{nd} order dispersion zero within 300nm in wavelength to an input pulse source, and exhibits a 3^{rd} order dispersion lower than or equal in absolute value to an absolute value of the 3^{rd} order material dispersion of silica.